Wildfire Management at Aggtelek National Park, Hungary

Integrated Vegetation Fire Management

Agoston Restas
Szendro Fire Department
H – 3752 Szendro, Varalja ut 3,
Hungary
arestas@tuoszendro.hu

Abstract: *Szendrő Fire Department is located in the northeastern part of Hungary. The main task is to fight against wildfire and mitigate the impact of fires at the Aggtelek National Park, which belongs to the UNESCO World Heritage list.*

In 2004 the Fire Department started a project called Integrated Vegetation Fire Management (IVFM). The IVFM consists of two main components: Peripheries and Modules. Two of the modules are based on remote sensing technology. The Tower Based Environmental Monitoring and Fire Detection Module informs the Fire Department once fires in their early stages are detected.

The Dynamic Decision Support Module is based on Unmanned Aerial Vehicles (UAV), which is able to fly around the fire and monitor it. This data, combined with the GIS - based fuel model and other information enables to predict fire activity, supporting fire management.

Keywords: *IVFM, Peripheries and Modules, Remote Sensing, Tower based wildfire detection, UAV based fire monitoring,*

I. INTRODUCTION

Geographically, Hungary lies in the Carpathian Basin at the centre of Europe. Politically and economically it is among the Eastern European countries that joined the European Union on 1 May 2004. Hungary has an uneven division of forest cover. Statistical data shows that there are approximately 1712 thousand hectares of forested territory, which is about 18.5 percent of the country's territory.

In common with numerous other countries over the past decade, vast forested regions were destroyed by fire in Hungary also. Having experienced the sluggish and ineffectual central response, a number of local initiatives were started to increase effectiveness in forest fire situations, among these the Integrated Vegetation Fire Management Program of the Professional Municipal Fire Department of the Town of Szendrő is the most comprehensive. The program was also driven by the Department's responsibility for fire protection in the area of the Aggtelek National Park with its cave-systems that form a part of the UNESCO World Heritage Sites scheme. The program began in early 2004 and the date of its accomplishment will largely depend on the schedule of financial opportunities, but at the earliest it will be in 2007. The first step is the processing of information acquired during recent fire events and, based on that, the outlining of a concept.

II. STUDY

The Diary of Events of Borsod Abaúj Zemplén County's Catastrophy Prevention Directorate was used for the analysis, this contains data from nine fire departments including Szendrő's. The survey embraces the period from 1 January 1999 – 31 December 2004. Its aim is to offer factual confirmation, based on the Diary, concerning problems that arise and are known through experience in fighting vegetation fires. Conclusions springing from the results of the study and from other data resources are that:

1) We accept the phenomenon of global warming as a fact. A plethora of literature underpins the conclusion that it has resulted in an increase in the number and duration of periods of drought (1). The annual precipitation in the Carpathian Basin is not expected to change, but its distribution will alter (2). Declining precipitation will appear within shorter periods but with greater frequency or with increased local concentration. Dry periods will become longer, which leads to a higher degree of plant desiccation, thus offering more favourable conditions for ignition, combustion and spread of fire (3). Overall, the border of fires characteristic to the Mediterranean region can be expected to push northwards (4).

2) The 'fire seasons' are relatively easy to predict on the basis of meteorological conditions and experience (5), despite which the effectiveness of preventive measures (e.g. fire-lighting ban) is strongly questionable.

3) Experience shows that humans contribute around 80-90 percent of the causes for the emergence of fire (6). An improvement in civil discipline could lower this proportion a very great deal.

4) In intentional fires or those resulting from negligence the person causing the fire has little motivation to rapidly inform fire fighters. The time within which a fire is reported can be influenced by several factors, such as the interest of the person in reporting it, or the possibility for doing so. Land-line telephones are available only in inhabited areas, while the use of mobile telephones is atypical of those characteristically causing fires. In certain areas the lack of signal strength is also an obstacle in using mobile phones.

5) In the current system the fire department becomes aware of an emerging fire after this has been reported. No civil report means no fire. This is defined as *passive cognisance*. Signalling systems, applied in closed spaces, signal the emergence of a fire to the centres without human contribution and eliminate subjective judgement. This principle is termed *active cognisance*.

6) During the fire season interventions in effect often need to be carried out simultaneously at several locations. Units rush from one fire to the next, thus often the unit reaches the plot with a considerable loss of time following the

report. This results in more widely-spread fires that require more time and resources to extinguish.

7) The current system ties up resources for fighting fires that do not cause financial loss in a way that needlessly increases the potential risk for citizens resulting from an absence of fire-hoses. For as long as hoses, that are designed for effectively fighting fire and damage with an urban character, are tied up in the extinguishing of fires without financial loss, the rescue of those in directly life-threatening situations resulting from a different type of damage (accident, escape of dangerous substance into the atmosphere, etc.) may incur a time-loss that causes a substantial tactical handicap and a serious and unacceptable delay due to the absence of hoses.

8) The large numbers of fires emerging in unison often necessitates the simultaneous use of all fire engine hoses available in a given territory. At times hoses for fires cannot be requested at all, or only from distances that the long haul considerably lowers their productive and effective use. This may induce the raising of the degree of alarm. In such cases the defined order of help cannot be complied with and the otherwise logically structured Alarm and Help Plan breaks down.

III. INTEGRATED VEGETATION FIRE MANAGEMENT

A. Peripheries

The effective operation of and the conditions for IVF Management are ensured by the so-called *peripheries*. These include sufficient public education, PR activity, special training for firemen, the issue of area-use, media information, the opportunity for necessary international co-operation (7) (8) and, unavoidably, financing! The peripheries are established parallel to the modules. The most critical point is the issue of financing the system. With the application of the cost – profit principle financing cannot be separated from the perspective of effectiveness. The system can be considered more effective than that currently employed if there is cost-saving at the state-economy level. When examining the issue of effectiveness, returns from investments and the timing of returns are usually taken into consideration. There is sense in discussing the effectiveness of fire-fighting in this way as well, however, the explanation differs from the classical interpretation. In fire-fighting and other interventions the measures of effectiveness include the preserved value, which is often difficult to express as an objective figure, or the smallest possible scale of damage. An intervention or fire-fighting can be termed *effective* if the largest possible proportion of the saved value is achieved with the resources and equipment available, or if the damage is of the smallest possible proportion (9).

Investigations into the economic effectiveness of IVFM lie in an analysis of the economic loss – time function (10) and of the fire-fighting procedure. The study of the economic loss – time function is usually correlated to a closed space, where the so-called *fire-graph* initially rises exponentially then flattens out with the diminution of available combustible material before finally, with the exhaustion of the material, the graph ends.

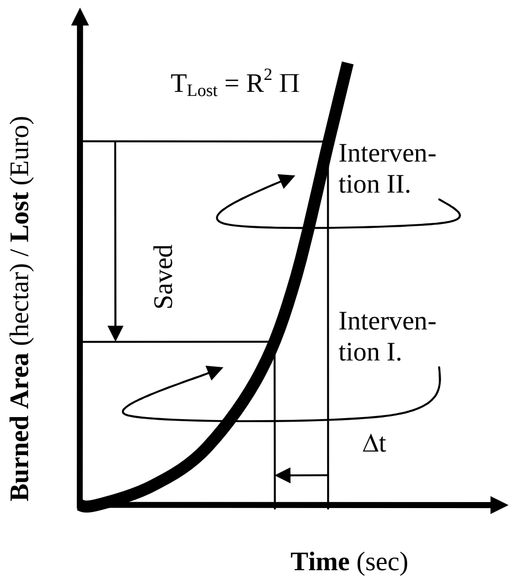

Fig. 1. Damage – Time Function

In the case of forest fire the financial loss – time function shows an exponentially rising curve rising into infinity. The rise of the curve is determined by two factors: one comes from the calculation of the area of the circle which is the same as the second power of the radius; the second springs from the speed of velocity of the fire per single time unit. The two are not really divisible. In brief and simple terms: the size of the burnt area per time unit depends on the speed of fire velocity, which changes quadratically per time unit. The faster the fire's velocity, the larger the burnt forest area. In ideal conditions this goes on infinitely. It is clear that decreasing any Δt (finite difference in time), the size of the burnt area and thus the financial loss diminishes along an exponentially rising curve. The two very simple verdicts drawn from the infinite and exponential curve are the following:

1) The closer we can get to the moment of lighting-up, the easier it is to fight any given fire.
2) Accepting the limitations of the fire-fighting capacity of a unit it becomes clear that after a certain time a given fire can no longer be fought without help.

The analysis of fire-fighting ascertains a number of statements. The fire department becomes aware of the report through someone noticing the fire. The reporting individual's subjective assessment considerably influences the time of notification. The notification is independent of the fire department, the link between the report and the time of lighting is often simply the reporting individual's subjective assessment. Fire departments currently endeavour to increase the rapidity of reporting through the method of awareness-raising. Following the report the fire brigade reaches the location of a fire, or at least approaches it, with the minimum delay in accordance to its operational order. This time period cannot practicably be lowered, and thus can be seen as being objectively set and minimal. Approaching the fire on foot could cause loss of time if there were a suitable path that was more rapidly negotiable by a cross-country vehicle. That is dependent on the technical tool, a vehicle. At the scene of the fire the first task is investigation, which is simply gathering sufficient information to facilitate effective fire-fighting. The effectiveness of the investigation can be measured by the efficiency of the fire-fighting. A sufficient amount of quality information is needed for that. The first job is to establish the extent of the fire. A burning area of only 300 metres radius represents a walk of nearly 2000 metres. Accounting for the configurations of the terrain, the obstructive effects of plantation and equipment, exploration on foot may extend in time considerably. Investigation from the air resolves these problems, and this can be achieved by an on-location deployed unmanned aerial vehicle (UAV).

Conclusions drawn from the fire-fighting procedures:

1) The time that has passed before a fire is reported does not depend on the fire department, but does lead to a delay in intervention
2) Time from the report to arrival at the location cannot objectively be reduced
3) Reaching the location on foot results in delayed intervention
4) Investigation on foot extends in time and results in a delay in the commencement of effective intervention

Both the analyses of the financial loss – time function and of the fire-fighting procedure show that effective fire-fighting depends most on the time factor. Rapid intervention calculated from the point of lighting appears firstly in reduced financial loss and secondly in reduced costs for deploying forces and equipment.

B. Modules

The second part consists of three modules:

1) Tower based fire-detecting unit
2) A mobile deployment control and support unit
3) Static and dynamic decision-support unit
4) Complementaries (e.g. module aimed at fighting large-expanse fires)

IV. TOWER BASED FIRE-DETECTING UNIT

The centrally installed monitoring and fire-detecting unit is the system's first module, which employs active detection in the place of the current passive system. Szár Hill, 520 metres tall and located near the geometric centre of the area of operations of the Szendrő Fire Department, has had a 120m tall broadcasting tower installed on it. The promontory is the most important point of elevation in the region, and allows a large area to be monitored from there without any visual occlusion. In the course of the project two rotatable cameras would be installed on the first floor of the tower at a height of approx. 50 m, which would transmit to the dispatching centre of the Szendrő Fire

Department. The duty officer will be able to detect any fire or smoke within a very short period from a fire igniting, and before it would be reported by telephone by anyone. The cameras, which have appropriate resolution, will also be able to generate automatic signals or alarms, depending on their settings. The accuracy of both automatic alarm signals and personal detection will deteriorate in proportion to distance, but even at the edge of the area to be monitored, defined as a circle with a 13-17 km radius around the tower, it will have to comply with the perceptual threshold of 160 m2. The above shall ensure, both on the detection and the alarm side, that under normal conditions the unit arriving to extinguish the fire will be confronted by a vegetation fire that they are able to extinguish using their own resources.

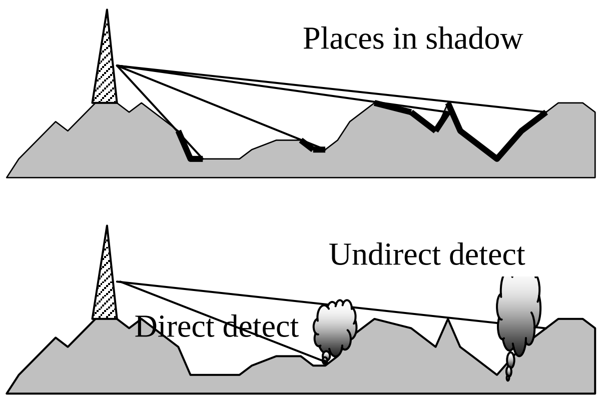

Fig. 2. Tower based Fire-Detecting Unit

The geographical features allow fires to be detected within a short period of their starting, either by direct visual observation of hillsides, in the valley of the Bódva and on unoccluded hillsides, or, depending on the location, directly or indirectly in the valleys of others and indirectly by detecting the smoke rising from occluded hillsides. Fires in valleys and in lower-lying areas can be detected by detecting pillars of smoke. When the smoke rises over the ridge of the hill occluding the area, it can be detected by one of the cameras. The relatively small height differential between ridges and the lowest points of valleys (50m – max. 200 m) will allow even the pillars of smoke from small fires to be detected, despite the mixing of air and the resultant 'thinning' of smoke.

V. MOBIL DEPLOYMENT CONTROL AND SUPPORT UNIT

The mobile deployment control and support unit is the system's second module. Once a fire is detected, it is crucial that the site be reached as soon as possible in order to perform precise reconnaissance of the fire, and to commence extinguishing using the appropriate tactics. At present, since the roads are not negotiable by fire-engines, fires are often accessed on foot over distances of several kilometres, on some occasions with a fire-hose, which carries the risk of the hose being damaged or caught. The above considerations justify the use of a vehicle with strong all-terrain capabilities to access scenes of fire. The vehicle would also allow the traditional and modern equipment that is widely used in international practice to be transported to the scene (11).

VI. STATIC AND DYNAMIC DECISION – SUPPORT UNIT

A. Static Decision Support

Appropriate information is a precondition for tactically correct intervention, which presupposes accurate reconnaissance performed by the leader of the fire-fighting unit. As areas are usually accessed from the direction of valleys, a good overview of the area affected by the fire is generally not available. Walking around the fire is time-consuming and, in the case of a larger area under flame, the leader of the fire-fighting unit is evidently physically too close to the fire to be able to make the correct decision concerning the type of intervention based on an assessment of both the fire and its environment (12). International practice has produced a few examples for establishing the velocity of the fire based on preliminary calculations (13) (14).

The above data-series can determine the velocity parameters of a fire if summarised with a mathematical algorithm (spread prediction model). This is the static fire velocity calculation that can be displayed for the fire-fighting leader on a digital map (3D – terrain model) on an on-site laptop. If we also summarise the parameters of the current weather conditions (temperature, humidity, speed and direction of wind), then the anticipatable fire velocity in accordance to situation at the time can be seen. All the data that may be represented in a map shall be stored in digitised format. User-friendly programs will also allow the risk levels of the area to be displayed in real time. Hence, instead of estimates concerning the spread of the fire based on previous experience, the likely spread of the fire can be determined on the basis of real, objective data.

B. Dynamic Decision Support

Accurate and rapid reconnaissance shall be facilitated by a special unmanned aerial vehicle. The flying unit will support integrated decision-making based on geographic information systems. This is justified by the articulation of the terrain and the plant communities characteristic of the area, which can delay or even prevent accurate, rapid reconnaissance. Thus, serious delays in determining the correct emergency level and defining the correct fire-fighting tactics in time for them to be used can be incurred. This instrument, which can be deployed on site immediately, and which can provide an accurate and comprehensive view of the fire situation can eliminate the delays and inaccuracy caused by difficult terrain (12).

The possibilities for employing a robot aircraft: With the use of a special 'pencil' the fire-fighting leader draws the path or give some turning points of reconnaissance on a map displayed on a laptop. This is not difficult since the leader is able to judge the approximate size of the fire, but this is not yet enough to satisfy the preconditions for effective fire-fighting. The robot converts the path received onto the digital map stored on the machine's memory. Using its built-in GPS system, the robot, which can take off vertically, flies along the specified path and transmits a continuous, real-time image to the display of the laptop computer from the camera (thermal camera) that it carries. The accurate visual information received on the parameters of the fire (dynamic element) can be transformed onto the digital map as quickly as possible. If we now connect the hottest spots with a mathematical algorithm, objective information about the fire's exact line can be determined. Thus the fire-fighting leader can obtain information about a given fire that can satisfy the demands of effective fire-fighting, within a minimal amount of time.

Fig.3. Reconnaissance by UAV

VII. CONCLUSIONS

Integrated Vegetation Fire Management involves a number of applications that have an innovative character in Hungarian fire-fighting. The system does not condemn the principle of fire extinguishing in the traditional way, it is complementary to it. It is a local initiative that emerged to tackle local problems. However, favourable experiences from the system's application could also be adopted elsewhere in Hungary. Its effectiveness has to be judged on economic rather than emotional grounds. IVFM is not a cost-free system, it could not possibly be. If we accept that the efficiency of the current system is not optimal for fighting vegetation fires, then the reserves of the system not simply ought to be, but must be exploited. The analysis and its conclusions demonstrate that the premise of effective fire-fighting depends on the speed of intervention. As long as a time-reserve, unexploited in the current system, exists prior to the initiation of fire-fighting, using it is more than a possibility, it is an obligation.

The Area Monitoring and Fire Detection Unit installed on the tower ensures, from the perspective of recognisance and alarm, that the unit arriving for action will face a vegetation fire that in can fight with its own forces. The Mobile Deployment Control and Support Unit ensures an optimal approach to the fire and that the Static and Dynamic Decision Support Unit will reach the location. The tried and trusted principle of air-reconnaissance can be available to even the smallest fire department through the use of the reconnaissance robot aircraft. Traditional reconnaissance does not offer information quantitatively nor qualitatively appropriate to standards of the modern era. The robot aircraft, suited to the demands of fire departments, and that can also be used by small fire departments, significantly contributes to solving that problem. The dynamic decision support is able to provide initial data for static decision support. Thus, instead of an estimate of fire velocity based on previous experiences, the fire's actual scale and velocity can be objectively defined.

The application of the IVFM is expected to result in increasingly effective interventions, which can achieve a growth in the size of preserved forest areas, as well as a decrease in the area of territory destroyed. The costs of development and application need to be judged on the basis of economic considerations, and seen as effective if returns are brought at the state economy level. The requisition of firemen may diminish, and the need for help may frequently be avoided. In the absence of superfluous requisitions the potential risk to the general public diminishes in a higher degree of fire-security.

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